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HIGH CONDUCTIVITY COPPER ALLOYS

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ABSTRACT OF THE DISCLOSURE

New and improved copper base alloys combining high conductivity with good strength, with the composition consisting essentially of from 0.1 to 2.5% chromium, 0.01 to 0.5% phosphorus, from 0.001 to 0.25% boron and the balance essentially copper, with the chromium boron and phosphorus precipitated throughout the copper matrix in a fine, uniform dispersion.

This application is a continuation-in-part of U.S. patent application Ser. No. 581,715, filed Sept. 26, 1966, for "High Conductivity Copper Alloys," by Elmars Ence, now abandoned.

It is, of course, highly desirable to obtain high conductivity copper alloys having good strength characteristics. However, alloys of this type are either not readily available or quite expensive.

In copper base alloys a common method for obtaining good strength characteristics is by alloying. Alloying, however, normally lowers the conductivity, for example, solid solution hardening depends upon keeping alloying additions in solution. This is mutually incompatible with high conductivity.

There are other strengthening phenomena, such as precipitation hardening, dispersion hardening, order-disorder reactions, and martensite reactions. These also require the presence of alloying additions which in general are not completely removed from the copper matrix and, therefore, detract from the conductivity of the alloy.

Accordingly, it is a principal object of the present invention to obtain high conductivity copper base alloys.

It is a further object of the present invention to obtain high conductivity copper base alloys having good strength characteristics.

It is a still further object of the present invention to obtain alloys as aforesaid at a reasonable cost.

Further objects and advantages of the present invention will appear hereinafter.

In accordance with the present invention it has now been found that the foregoing objects and advantages may be readily obtained. The novel alloys of the present invention consist essentially of from 0.1 to 2.5% chromium, 0.01 to 0.5% phosphorus, preferably 0.001 to 0.25% boron and the balance essentially copper. The alloying additions are precipitated throughout the copper matrix in a substantially fine, uniform dispersion.

In accordance with the present invention it has been found that the foregoing alloy retains high conductivity while having improved strength characteristics. For example, the conductivity of the foregoing alloy is in excess of 75% IACS and generally in excess of 85% IACS while the yield strength at 0.2% offset is in excess of 40,000 p.s.i. and generally in excess of 50,000 p.s.i.

The foregoing improvements are attained in part due to the specific alloying additions and in part due to a method of treatment which precipitates secondary hardening phases of the chromium, phosphorus and boron alloying additions and disperses them throughout the copper matrix, resulting in improved strength while retaining high conductivity. These secondary hardening phases may be in either elemental form or intermetallic compound form, or both. That is, the chromium, phosphorus and boron alloying additions in the foregoing amounts can be essentially precipitated from solid solution so that the copper matrix attains high conductivity but at the same time develops good strength through processing to disperse the hardening phases throughout the copper matrix.

In accordance with the present invention the improved copper base alloys contain from 0.1 to 2.5% chromium and preferably from 0.75 to 1.25% chromium. Phosphorus is present in an amount from 0.01 to 0.5% and preferably from 0.05 to 0.15%. It is preferred to use boron and in an amount from 0.001 to 0.25% and preferably from 0.005 to 0.05%. All percentages of ingredients are percentages by weight.

While excessive amounts of impurities are to be avoided, small amounts of impurities or other alloying additions may, of course, be tolerated provided that they do not greatly reduce the strength or conductivity characteristics. Also, naturally, alloying additions may be utilized in order to achieve a particular result.

In accordance with the present invention the melting and casting of the copper base alloys of the present invention are not particularly critical. The alloys may be melt and cast in accordance with conventional techniques for chromium bearing copper base alloys, e.g., the alloys may be prepared using conventional induction melting techniques with the alloying additions preferably made in the form of copper master alloys. For example, in order to provide reasonable melting temperatures, it may be advisable to use a 5 to 10% chromium master alloy, a 1% boron master alloy and a 10–15% phosphorus master alloy.

After casting the ingots are heated for hot rolling to a temperature of between 700 and 1000° C. and preferably 850 to 975° C. A holding time at this temperature of at least 30 minutes is preferred. The ingots are then hot rolled in the above temperature range to convenient gage, i.e., hot rolling should commence in this range. This hot rolling could, if desired, be the final rolling step. The amount of reduction in the hot rolling step is not particularly critical. If desired, the ingots may be hot rolled above 500° C. and preferably from 850 to 975° C., cooled if desired at any desired cooling rate, and solution heat treated as above, i.e., 700 to 1000° C., preferably 850 to 975° C. for at least 30 minutes. In other words, the order of hot rolling and initial heat treating may be reversed.

After heat treating and hot rolling, or after hot rolling and heat treating, the strip must be rapidly cooled to below 300° C. at a rate of not less than 550° C. per hour and preferably at least 550° C. per minute. This is necessary to maintain alloying additions in solid solution so that they may be subsequently precipitated in a proper dispersion to attain the desired strength and conductivity.

The alloy may, if desired, be cold rolled after rapid cooling. The cold rolling step is optional and depends upon gage requirements. The cold reduction step may attain a reduction up to 96% in one or more passes. The temperature of the cold reduction is not particularly critical but is generally below 200° C.

Whether or not the material is to be cold rolled, it must ultimately receive a thermal aging treatment which serves to precipitate constituents from solid solution and achieve the desired properties. This aging treatment may also serve as an interanneal or final anneal when cold rolling is used. This aging treatment should be at 250 to 575° C. for at least one hour and preferably less than 50 hours.

If desired, the strip may be interannealed once or more between cold rolling passes. Strip annealing techniques may be used, in which case the holding times are usually short, i.e., from 15 seconds to 5 minutes, and possibly as long as one hour, and the temperature is from 250 to 600° C. Batch annealing techniques may also be used, in which case temperatures of 250 to 575° C. for up to 24 hours may be used. If interanneals are employed, the total time at temperature for all anneals should preferably be less than about 30 hours in order to achieve preferred properties. Cooling rates from this temperature range are not critical.

As stated hereinabove, some time during the processing an aging treatment must be employed. This may be after the final cold rolling pass, if the alloy is cold rolled, or after the rapid cooling step if no cold reduction is utilized. The aging treatment may also precede a final cold reduction. This is a critical step of the present invention. The temperature of the critical anneal or aging treatment is from 250 to 575° C. and the holding times are at least one hour and generally less than 50 hours. The particular temperature and holding time chosen will depend upon the combination of strength and conductivity required. Normally, the aging treatment is conducted in a bell type furnace which has a controlled atmosphere, however, this is not essential.

If desired, the following modification in the foregoing procedure may be employed. After the rapid cooling step the alloy may be cold rolled, for example, at a reduction between 30 and 70%, at a temperature of below 200° C. This may be followed by the critical aging step of the present invention, i.e., at 250 to 575° C. for at least one hour. The alloy may then be cold rolled below 200° C., with reduction depending on gage requirements, followed by strip or batch annealing as indicated hereinabove. As many cycles of cold rolling and strip annealing may be used to reach desired gage. Optionally, this may be followed by another critical anneal or aging treatment, if desired.

The resultant alloy attains the aforementioned desirable combination of strength and conductivity. The alloying additions are precipitated in a substantially fine, uniform dispersion throughout the copper matrix.

The present invention will be more readily apparent from a consideration of the following illustrative examples.

EXAMPLE I

An alloy of the present invention was prepared by conventional techniques used for preparation of alloys of this type including an induction furnace, a suitable crucible material, and protection of the molten metal from oxygen by an inert or reducing atmosphere.

OFHC-grade copper was melted down and the temperature of the melt raised to about 1200 to 1250° C. Chromium was added as a copper-5 to 10% chromium master alloy. After the copper-chromium master had completely dissolved, phosphorus and boron were added to the melt in the form of a copper-10 to 15% phosphorus master alloy and copper-1% boron master alloy. The melt was then held at temperature for about 5 to 10 minutes during which time the melt was stirred and cast into cast iron molds. The composition of the resultant alloy was 0.9% chromium, 0.1% phosphorus, 0.02% boron and the balance essentially copper.

EXAMPLE II

The ingot prepared in Example I was hot rolled at 950° C. to 0.5" thickness and subsequently solution heat treated for one hour at 925° C. followed by water quenching to room temperature in 5 seconds. The resultant alloy was cold rolled to 0.025" gage.

High strength and high electrical conductivity was developed in two samples by final heat treatments of four and 24 hours at temperatures of 400 to 500° C. The properties of these materials are shown in Table I below with Alloy 1 being heat treated for four hours, and Alloy 2 being heat treated for 24 hours. Also shown in Table I below for comparison are properties of a copper-0.9% chromium alloy identified as Alloy 3 in the table below.

TABLE I

	Alloy 1	Alloy 2	Alloy 3
Yield strength—0.2% offset p.s.i.	70,150	69,800	45,000
Ultimate tensile strength, p.s.i.	74,300	74,000	50,000
Elongation, percent	11	13	15
Electrical conductivity, percent IACS	81	86	81

The microstructures of Alloys 1 and 2 were characterized as follows: The alloying additions were precipitated in a fine, uniform dispersion throughout the copper matrix.

EXAMPLE III

In a manner after Example I, an alloy was prepared identified as Alloy 4 having the following composition: chromium 0.9%, phosphorus 0.2%, balance essentially copper. This alloy was then treated as in Example II, with the final heat treatment being for four hours. The properties were as follows: yield strength at 0.2% offset—47,000 p.s.i.; ultimate tensile strength 56,600 p.s.i.; elongation 18%; and conductivity 85% IACS.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. A high conductivity, high strength copper base alloy consisting essentilaly of from 0.1 to 2.5% chromium, from 0.01 to 0.5% phosphorus, from 0.001 to 0.25% boron, and the balance copper, with precipitated secondary hardening phases of the chromium, phosphorus and boron dispersed throughout the copper matrix in a fine uniform dispersion.

2. An alloy according to claim 1 having a yield strength at 0.2% offset in excess of 40,000 p.s.i. and an electrical conductivity of at least 75% IACS.

3. An alloy according to claim 1 wherein the chromium is present in an amount from 0.75 to 1.25%.

4. An alloy according to claim 1 wherein the phosphorus is present in an amount from 0.05 to 0.15%.

5. An alloy according to claim 1 wherein the boron is present in an amount from 0.005 to 0.05%.

References Cited

UNITED STATES PATENTS

2,025,662	12/1935	Hensel et al.	75—153
2,148,151	2/1939	Darby	75—153X
2,183,592	12/1939	Silliman	75—153
2,195,433	4/1940	Silliman	75—153
2,254,944	9/1941	Hensel et al.	75—153X
2,281,691	5/1942	Hensel et al.	75—153
2,479,311	8/1949	Christensen et al.	75—153X
2,795,501	6/1957	Kelly	75—153

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75—153